Simulations of continuous and discrete event turbulence

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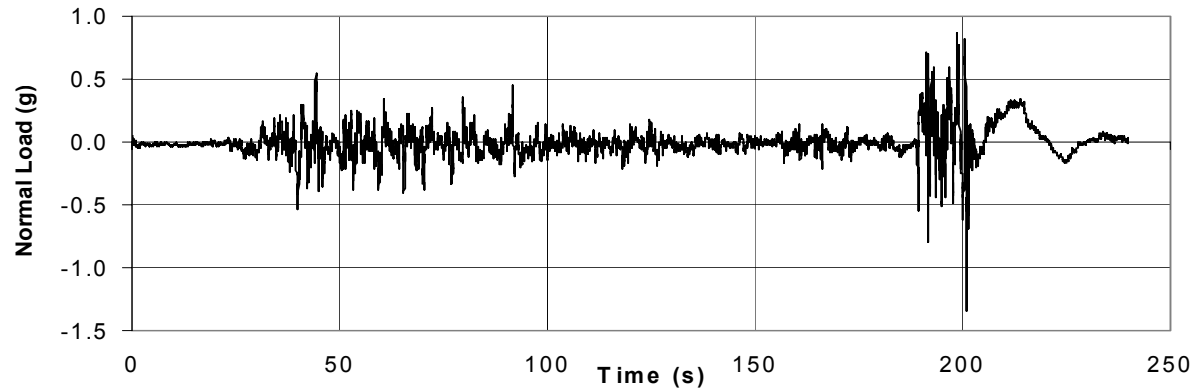
Boulder, CO

Second AvSP WxAP Annual Project Review
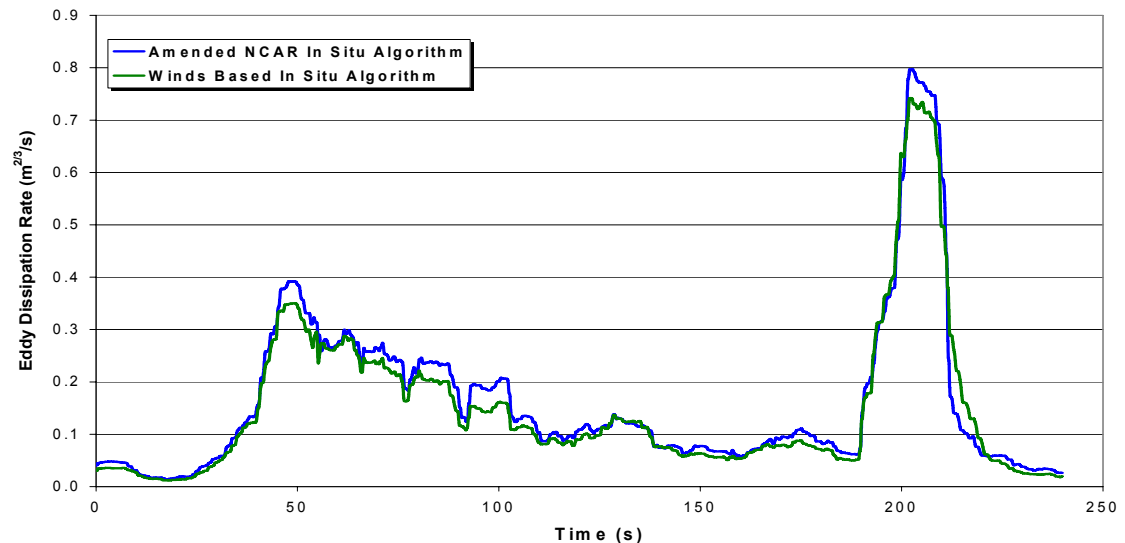
Cleveland, Ohio

6 June 2001

Continuous vs. discrete turbulence

☞ Measured vertical acceleration from NASA flight test

Wind derived vs ❖ in-situ algorithm

Continuous turbulence: Use of a von Karman representation

Advantages:

- Case studies show von Karman is a good representation
- Simple analytic formulation
- Only two parameters:
  - (correlation) length scale
  - intensity

Disadvantages:

- Larger scales may be misrepresented
- Computation that produces accurate spatial statistics is not so straightforward
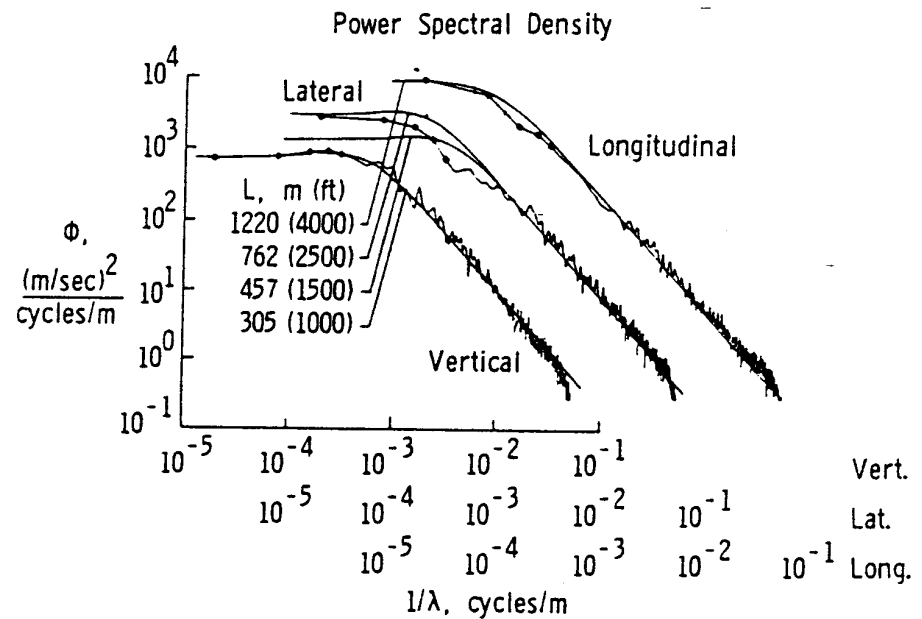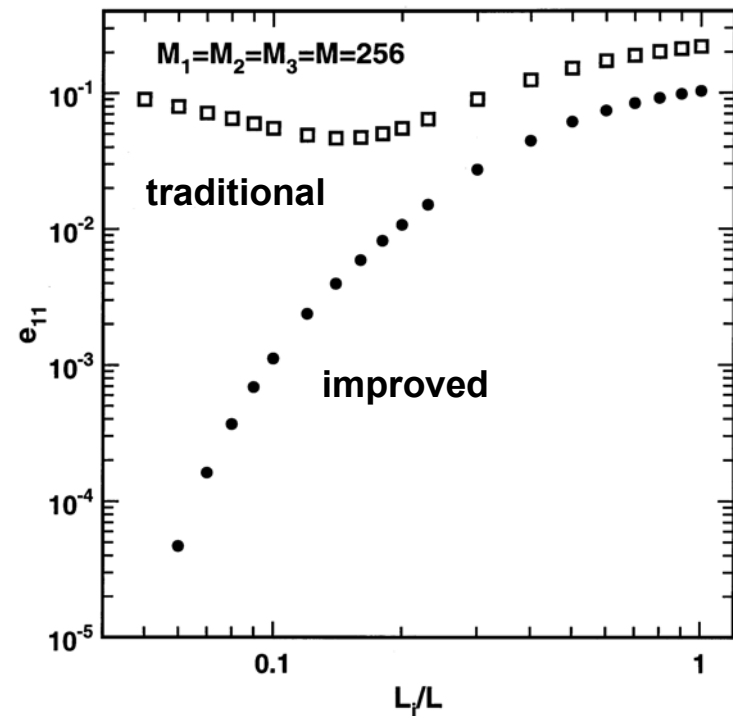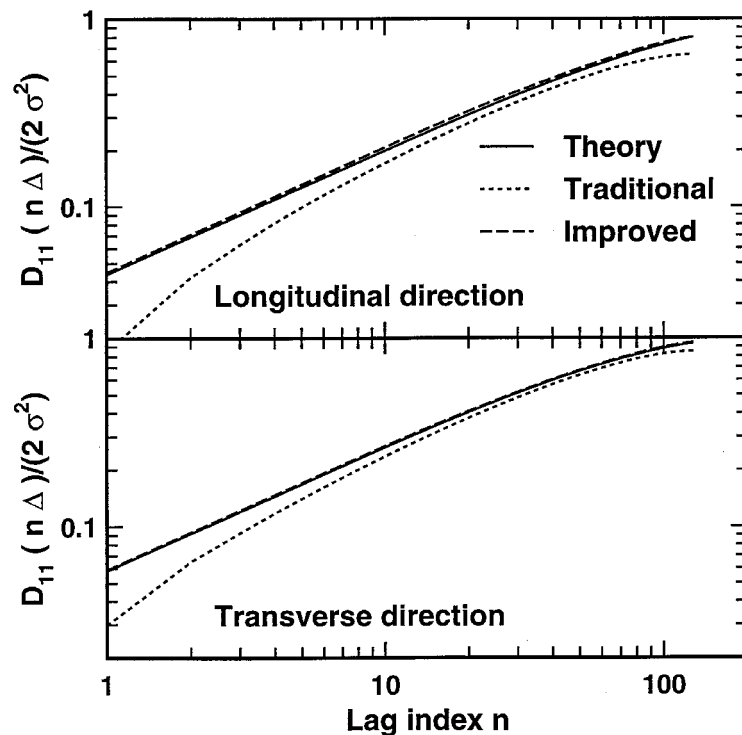

(b) Power spectral density.

Figure 5.   Convective case.

From Murrow, "Measurements of Atmospheric Turbulence", NASA CP-2468, 1986

von Karman Turbulence Simulations

- Uses technique of Frehlich, Cornman, Sharman which minimizes errors in structure (correlation) functions

von Karman Turbulence Simulations: Applications to radar detection

- Using von Karman turbulence data with known statistics + radar simulation allows evaluation of radar turbulence estimation algorithms
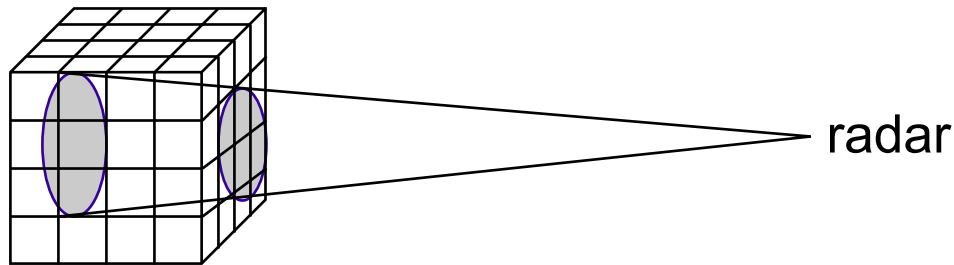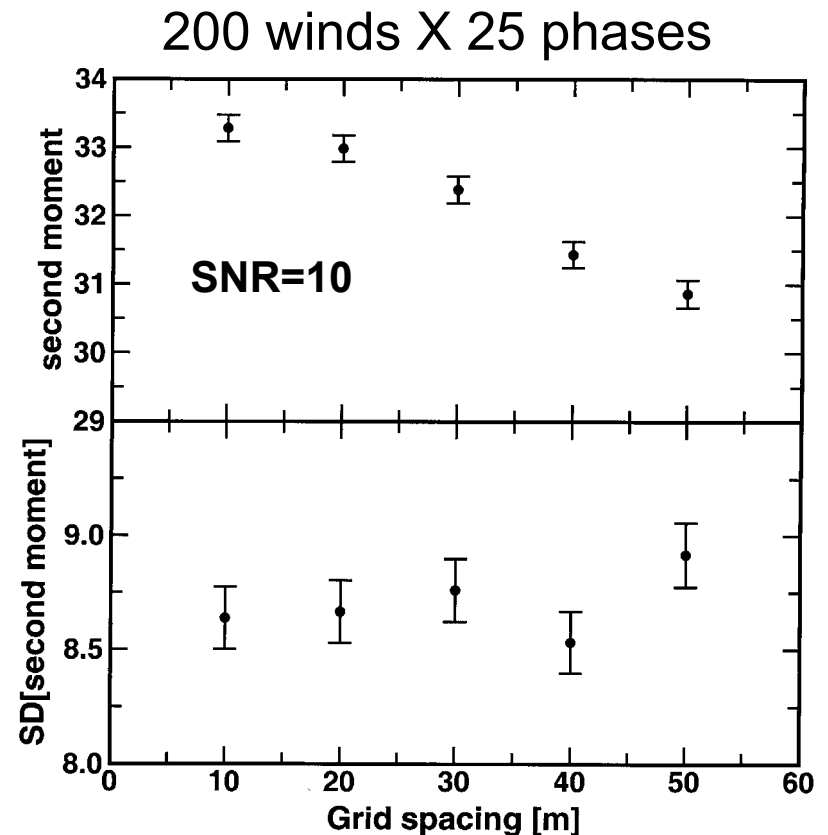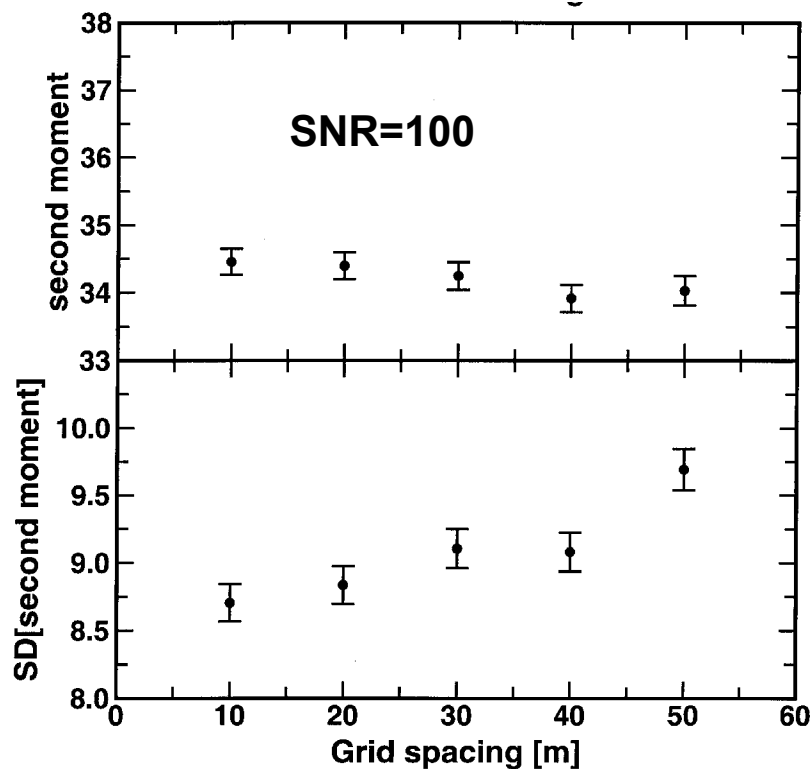

Von Karman gridded 3d fields of velocity and reflectivity

radar

# von Karman Turbulence Simulations: Applications to radar detection (cont.)

Q: What simulation grid resolutions are required?

**A: It depends!**

200 winds X 25 phases

# von Karman Turbulence Simulations: Applications to mesoscale cloud models

- Numerical simulations of clouds are good at resolving larger scales but smaller scales are misrepresented
- But von Karman is a good representation of smaller scales
- So add the two, modulating the von Karman intensities by the large scale resolved motion
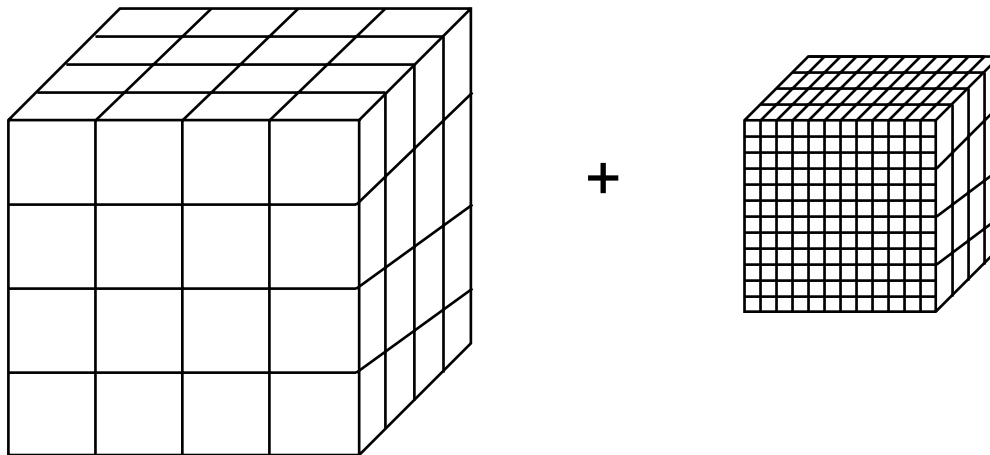
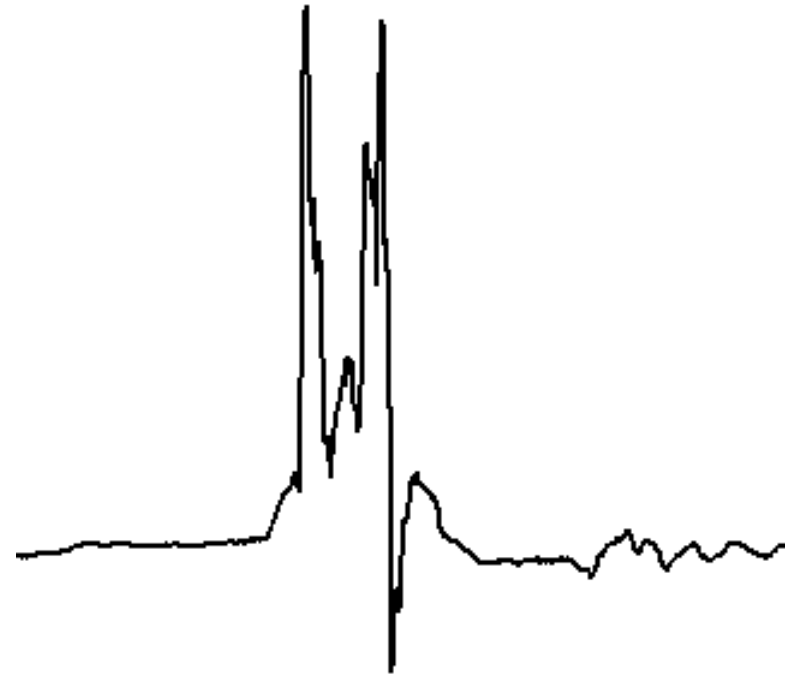# Numerical simulations + von Karman subgrid. Merged spectrum
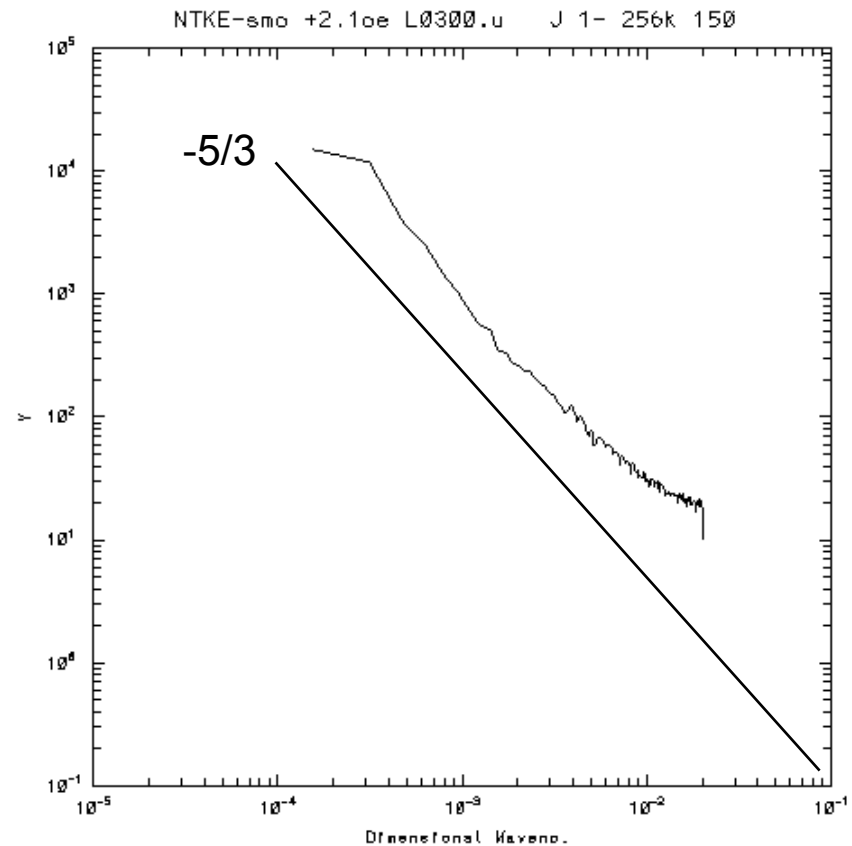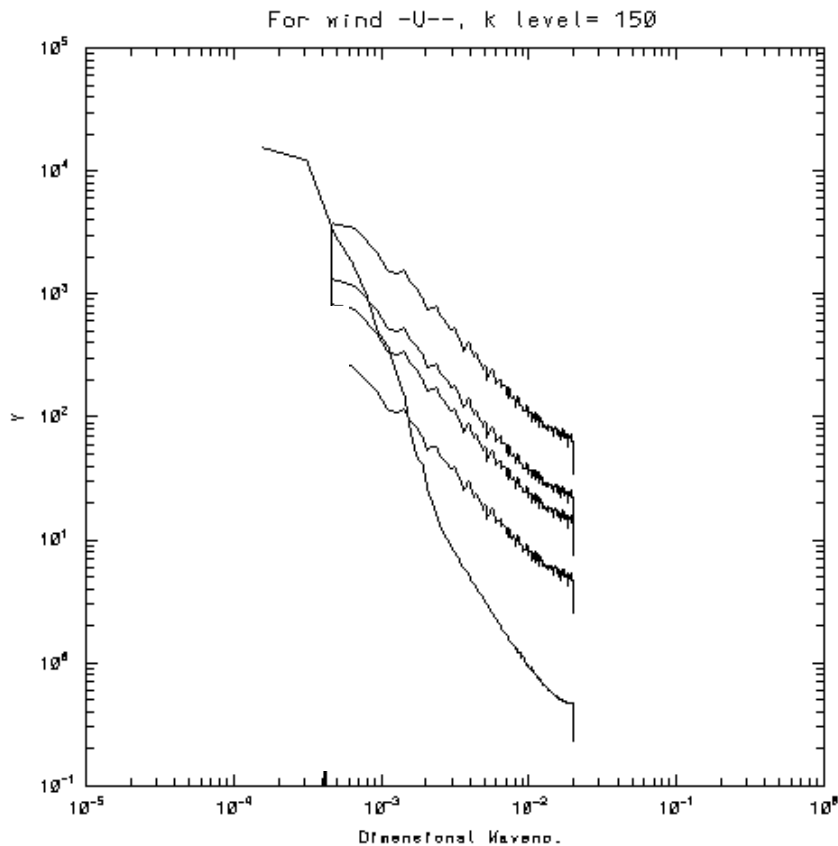
Numerical simulations + von Karman subgrid. Structure function fit and merger
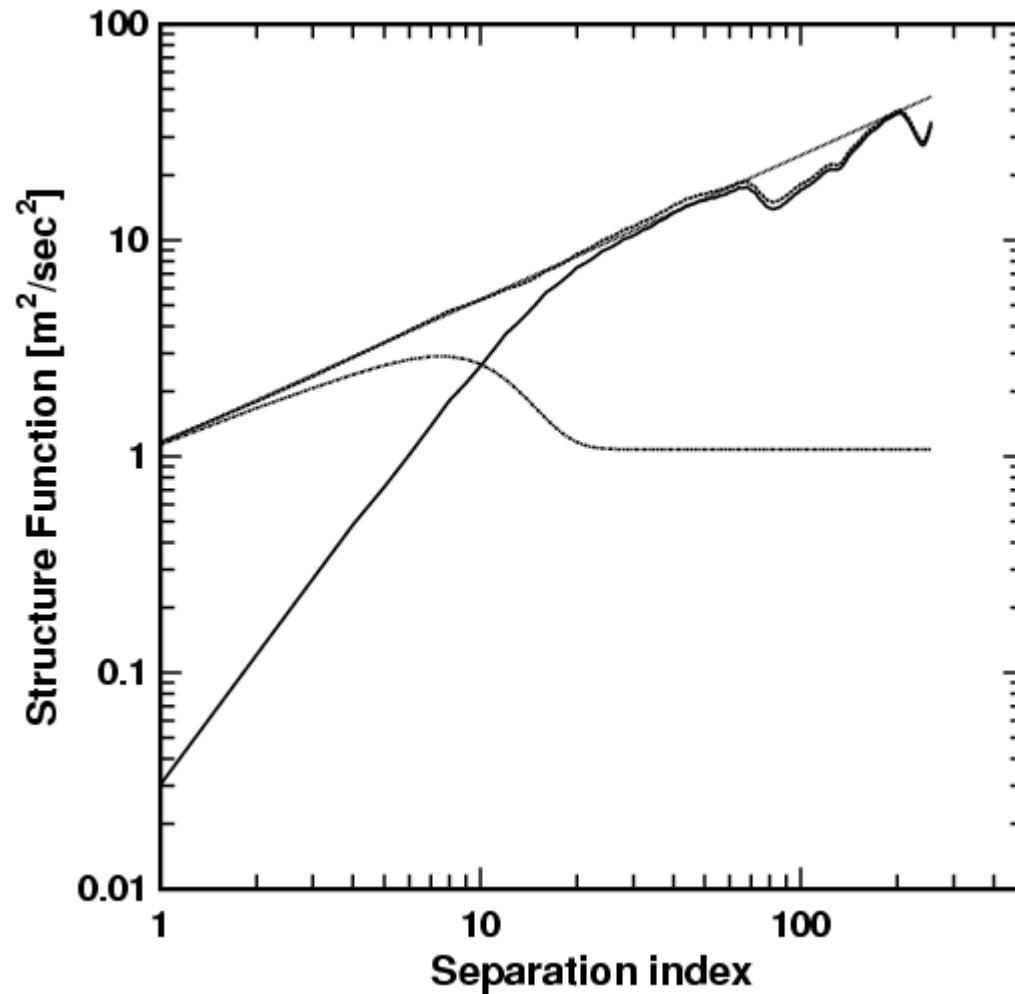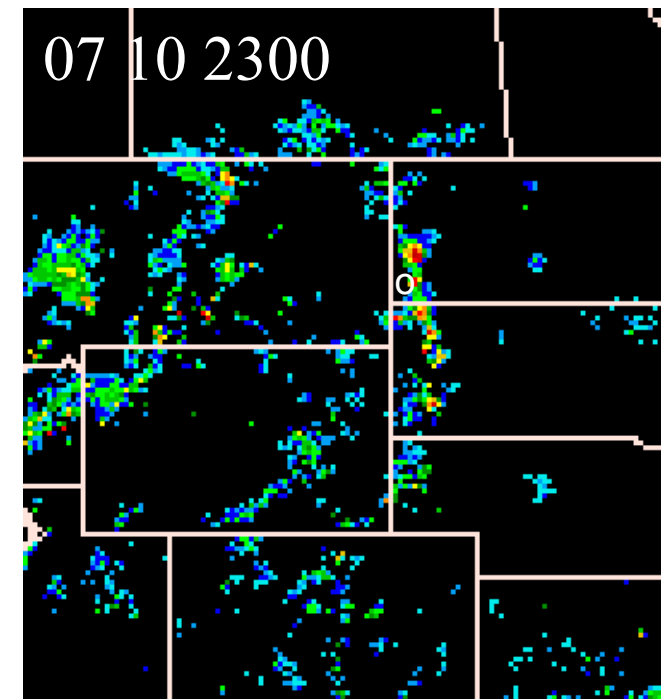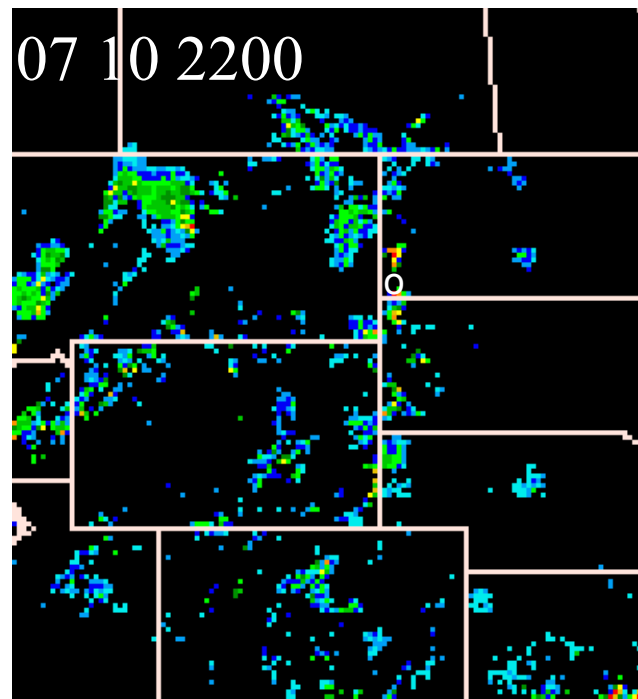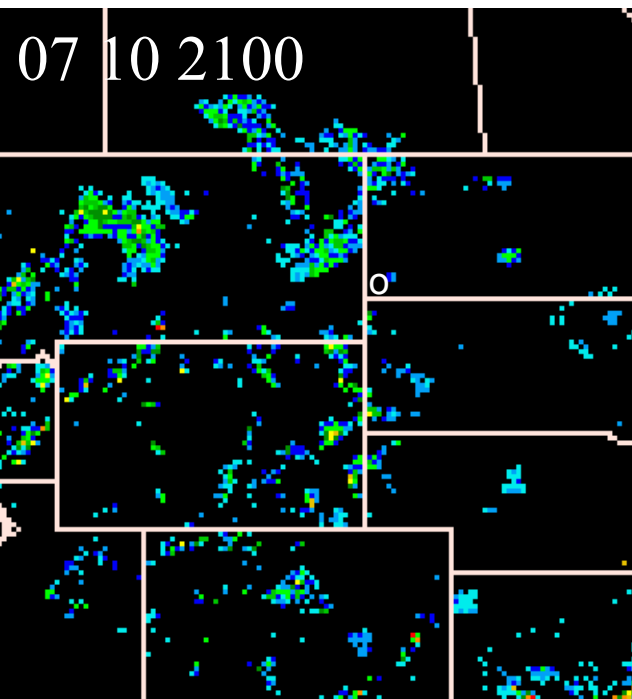
Discrete event simulation

- American Airlines 757 encountered severe clear-air turbulence at 37,000 ft enroute SEA-JFK 10 July 1997 2141 Z near Dickinson ND

- 12 sec, -.75 - + 2.01 g's

- 22 injuries, flight diverted to DEN
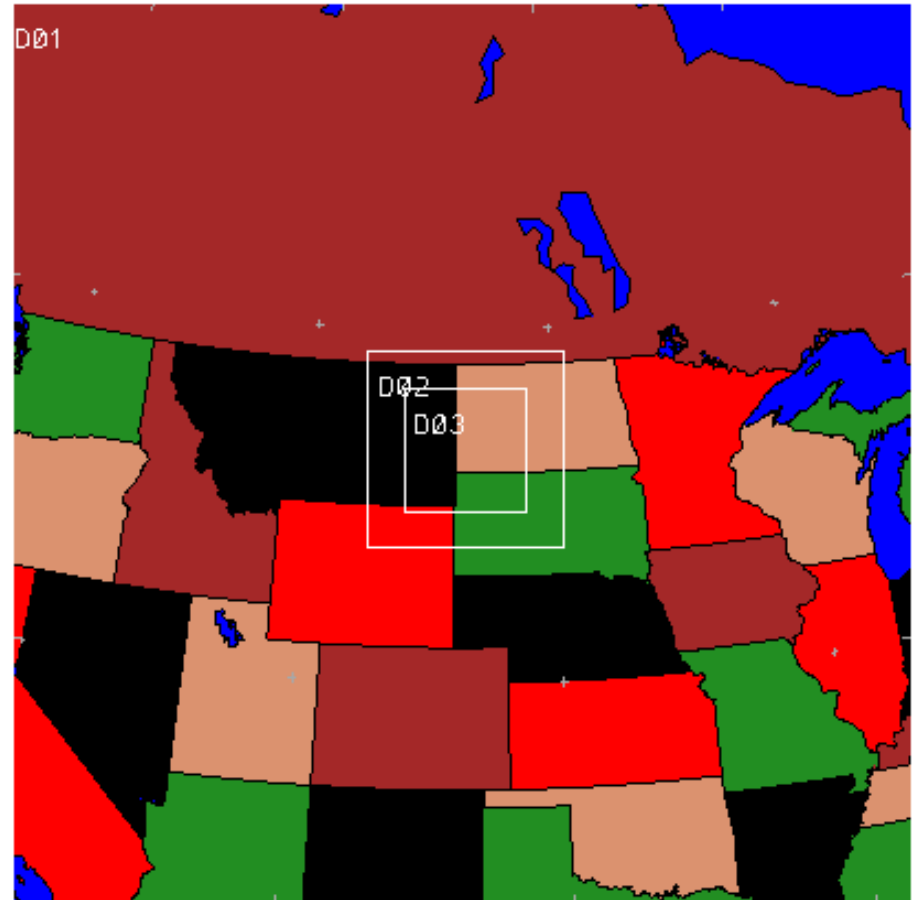
- No sigmet in area

Vertical velocity trace from FDR

Discrete event simulation (cont) - radar mosaic
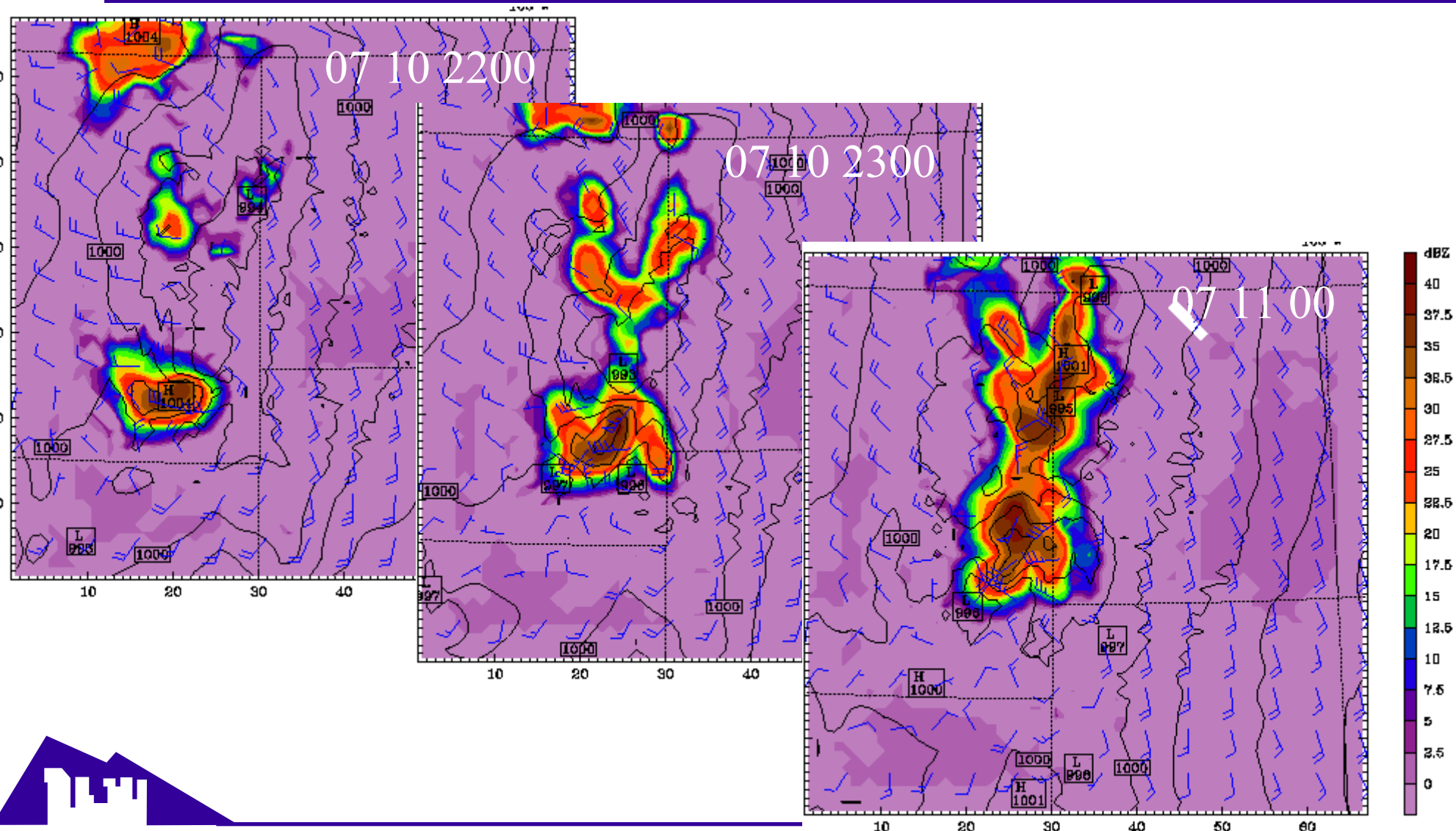

07 10 2100

07 10 2200

07 10 2300

Dickinson,ND discrete event simulation

- **3 step procedure**
  - MM5 simulation
    - triply nested grid (27,9,3 km)
    - 35 vertical levels
  - Clark-Hall cloud model
    - nested grids, highest resolution 50 m
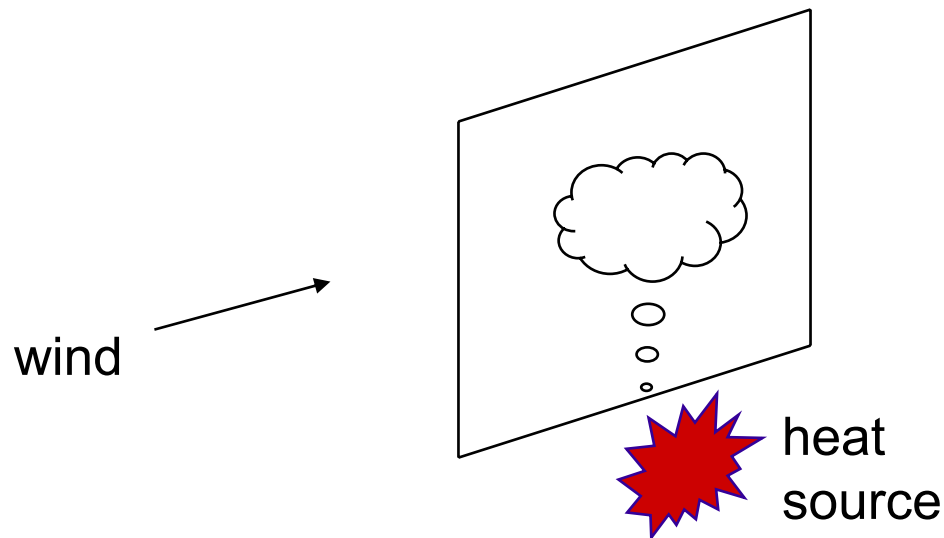 - Add subgrid von Karman

Dickinson,ND discrete event simulation - MM5 results
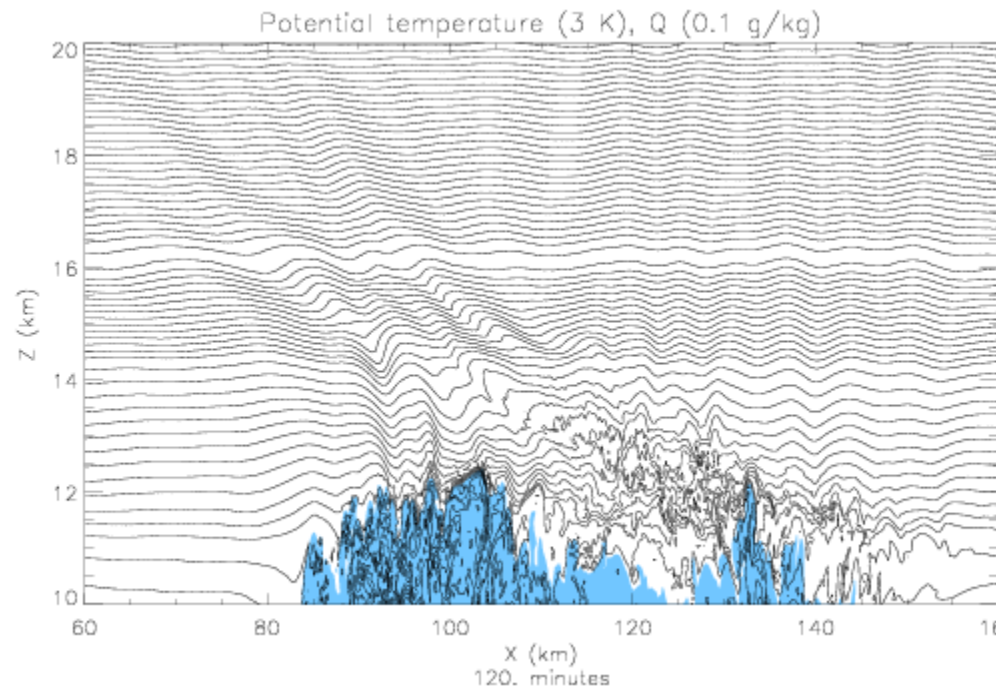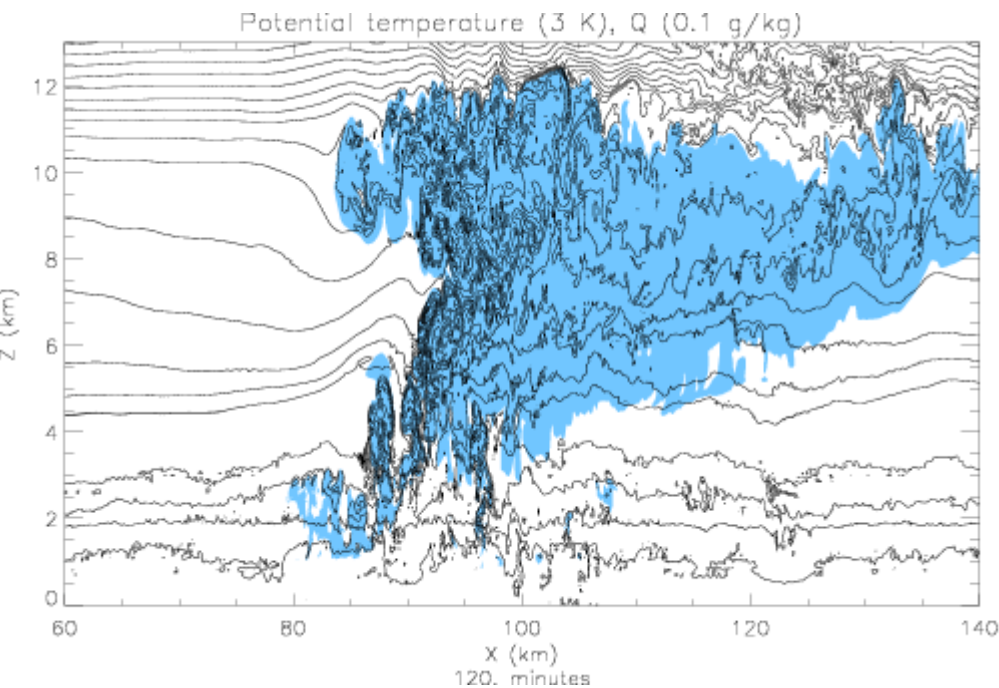

07 10 2200

07 10 2300

07 11 00

Dickinson,ND discrete event simulation - 2d high resolution simulations

- 2d simulations aligned with flow
- High resolution (16m) Clark-Hall cloud model
- Clouds forced by heated surface
- Initialized with Bismarck, ND 0Z sounding

wind

heat source

Dickinson,ND discrete event simulation -
2d high resolution simulations: results

Potential temperature (3 K), Q (0.1 g/kg)

Dickinson,ND discrete event simulation - 2d high resolution simulations: results